



Calpine Geysers Visitor Center Middletown, CA



CLEAN MODERN EFFICIENT FLEXIBLE POWER GENERATION

Project Objectives

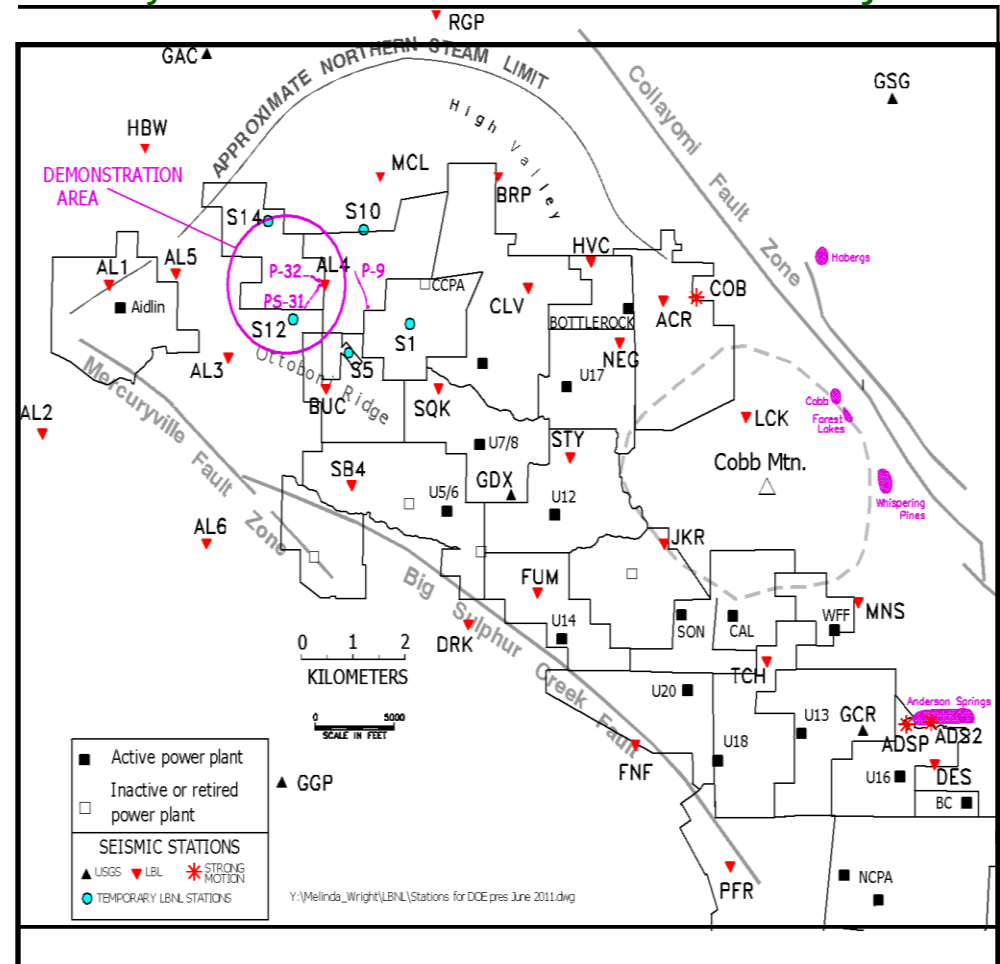
- Create an Enhanced Geothermal System (EGS) by directly and systematically injecting low volumes of “cold” water into NW Geysers high temperature zone (HTZ)
- Other objectives are:
 - Investigate how cold-water injection mechanically and chemically affects fractured high temperature rock systems
 - Demonstrate the technology to monitor and validate stimulation and sustainability of such an EGS



Project Motivations

- **Increase steam production.**
Use under-produced NW Geysers area.
- **Mitigate NCG concentrations in high temperature reservoir.**
- **Stimulate wells to enhance permeability.**
- **Achieve 100% mass replacement.**
Support sustained electrical production for future development.
- **Address public concerns on injection-induced seismicity.**

Nearby Communities to EGS Demonstration Project



Scientific/Technical Approach

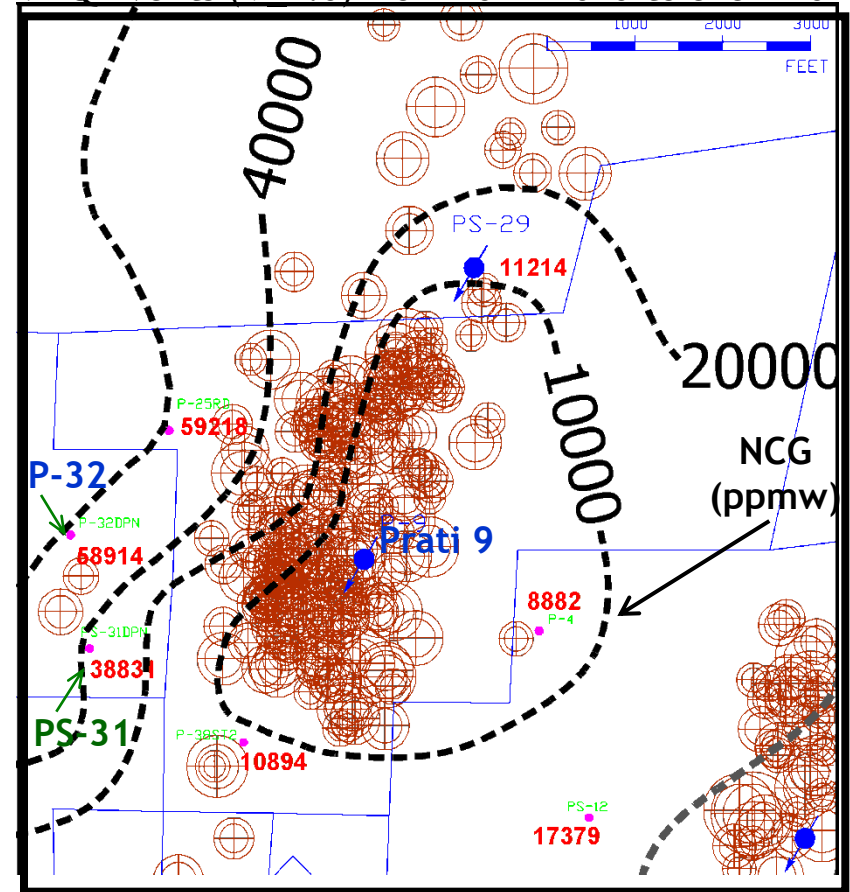
- Fieldwork (wells, pipeline, monitoring) will be managed by Calpine.

Calpine will repeatedly log the P-32 and PS-31 wells with its own Pressure-Temperature (PT) tools during the stimulation experiments.

- LBNL is conducting coupled thermal, fluid flow, and geomechanical modeling to:
 - Gain insights into underlying mechanisms of microearthquake events (MEQ's) and their role in enhancing permeability.
 - Investigate stimulation, injection and production strategies.

LBNL field monitoring and data analysis will be focused on 3-D tomography and high-precision location source studies of MEQ's.

Current MEQ Monitoring of Nearby Injection
MEQ Events ($M > 1.0$) from 10/1/2010 to 3/31/2011

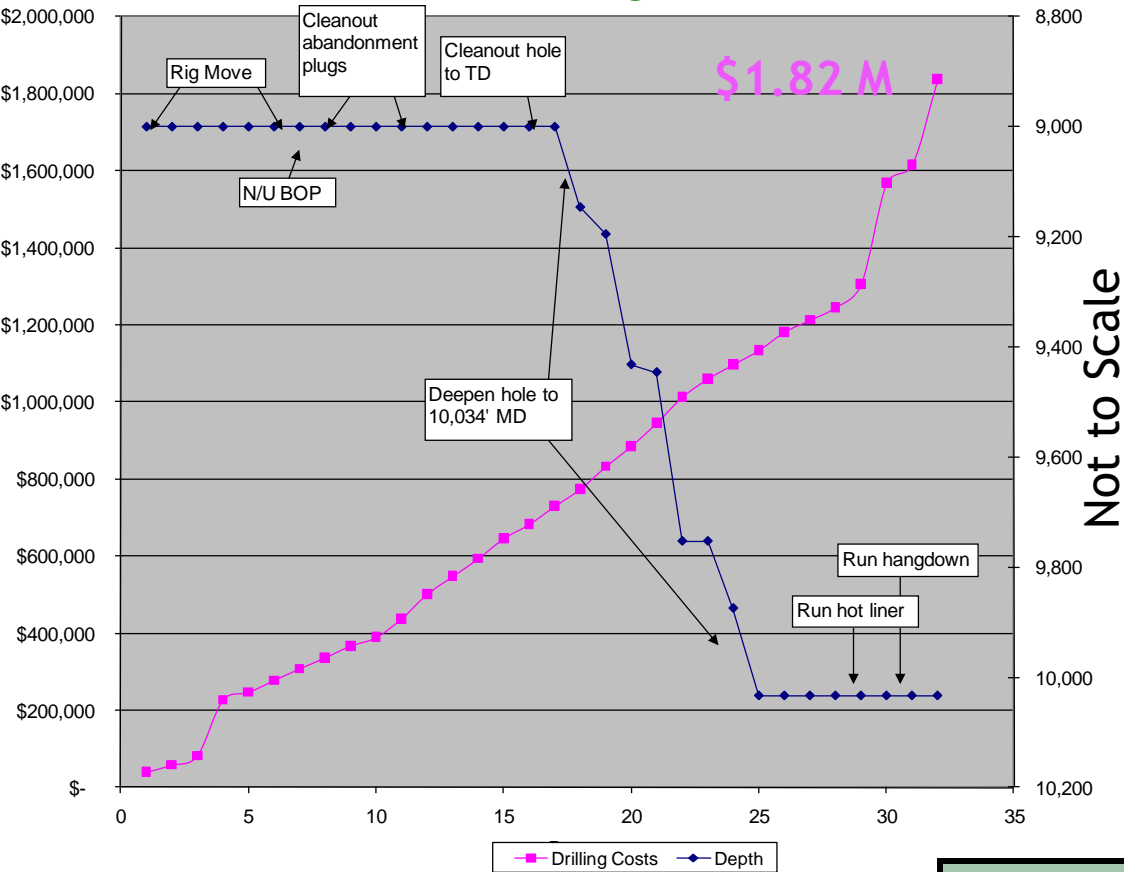


Prati State 31 Deepened in HTZ

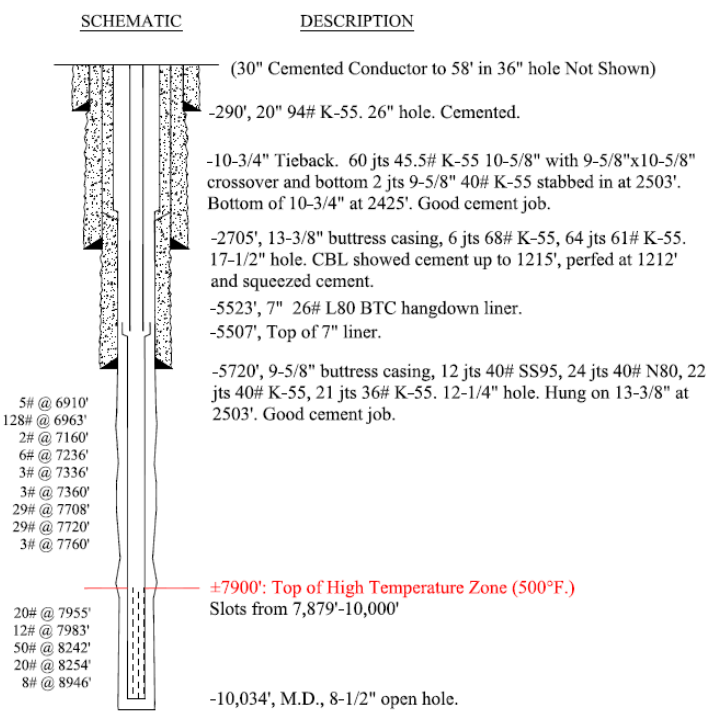
8/16/2010



Drilling



Completion



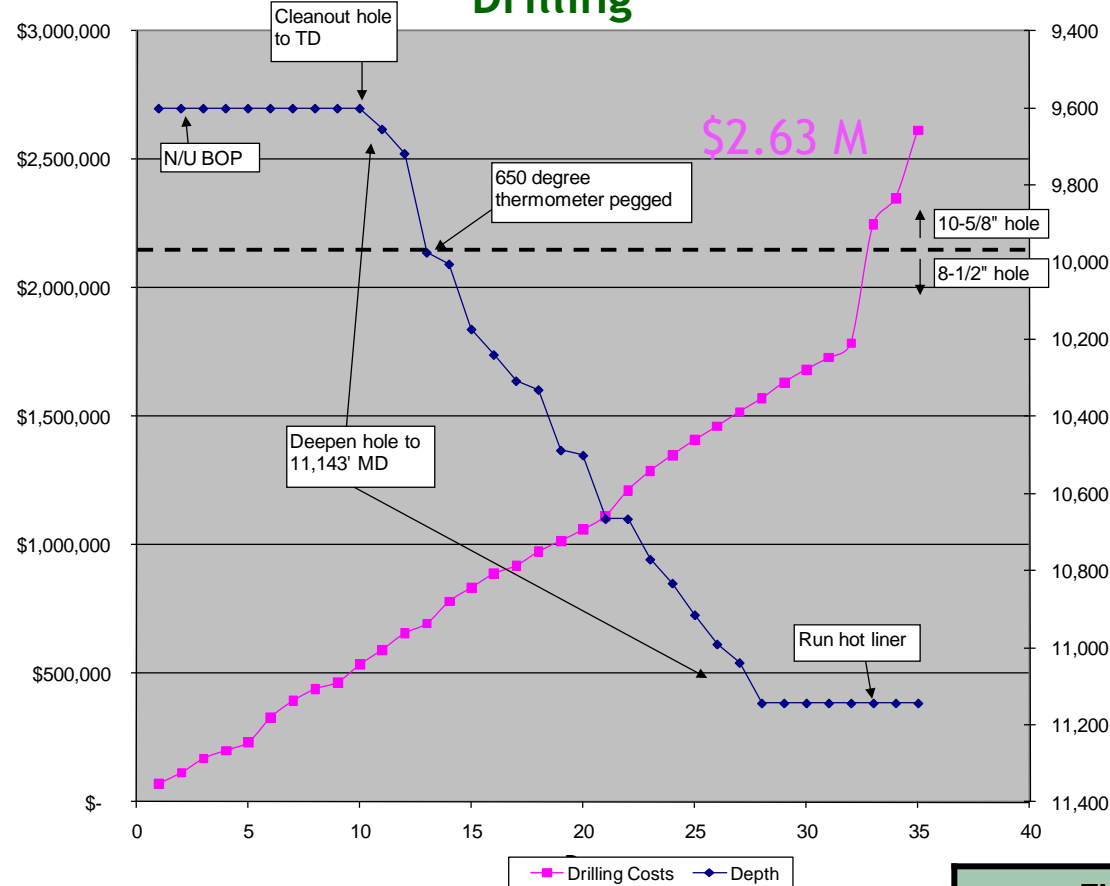
Test Results

WELL	Flow Testing			Geochemistry		
	KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H ₂ S (ppmw)	Cl (ppmw)
PS-31	43	100	320	3.9	1280	135

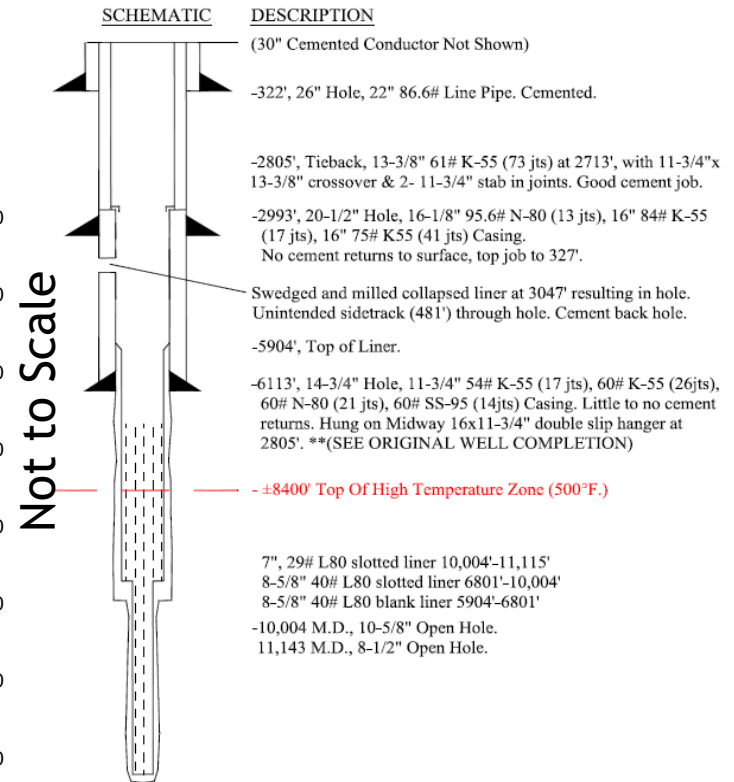
Prati 32 Deepened in HTZ

9/23/2010

Drilling



Completion



Test Results

WELL	Flow Testing			Geochemistry		
	KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H ₂ S (ppmw)	Cl (ppmw)
P-32	84	100	340	5.9	1380	72

Prati 32 Deepening



Prati 32: Final Bit at TD (11,134')



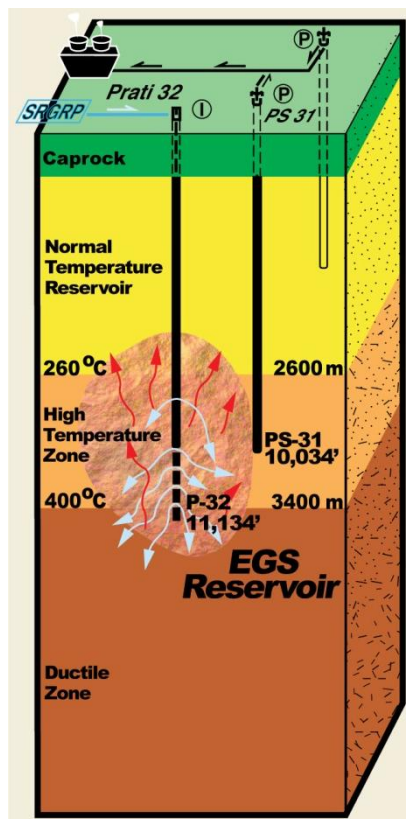
Average Bit Condition after 300'
of air drilling at the Geysers



Injection Water Pipeline for EGS Demonstration Injection Well

- Approximately 4800 feet of 10 in. and 12 in. diameter pipeline to P-32 pad were constructed. Cost: \$1.97M.
- Injection Flow rate data are updated within Calpine internal system - PI Data Capture - on about 15 second intervals.
- Injection flow rates and seismic events are continuously monitored from the first moment the stimulation experiment began in October 2011.





Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field, CA

May 7, 2012

Principal Investigator:
Mark Walters
Geysers Power Company, LLC
("Calpine")

Timeline

Project dates: 09/30/08 – 10/31/12

Phase completion:

- Phase 1 - Drilling and Injection pipeline
- Phase 1 - Public Outreach
- Phase 2 - Stimulation
- Phase 3 – Long-term Monitoring

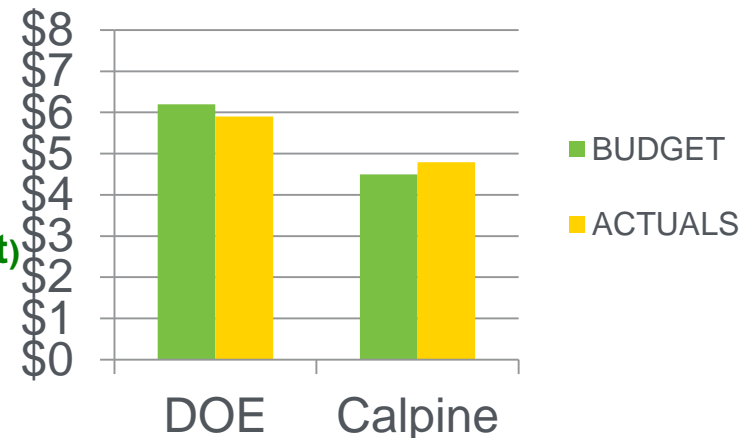
% Completion by Phase



Financial Status

- **Budget: \$10.7 Million (DOE \$6.2M / Calpine \$4.5M)**
- **Actual Spent to Date: \$10.7 Million (100%)**

- DOE \$5.9 M spent to date (94% of budget)
- Calpine \$4.8 M spent to date (108% of budget)



Application of Resources

Original shared costs: DOE 58%, Calpine 42%

Actual shares of total costs to April 1, 2012: Calpine: 45% or \$4,827,760

DOE: 55% or \$5,881,811

Integration with Other Projects

The EGS project geology/reservoir model will be refined with data resulting from the DOE ARRA grant for the Caldwell Ranch Exploration and Confirmation.

Variance

Prati 32

Originally completed as a producer

Completion encountered 750°F at 11,000' near permeable rock

Re-completed at Calpine's expense as an injection well

Installed blank injection liner directing water to the high temperature zone

Prati State 31

Originally completed as a injector

Recompleted as a production well

Perforation of blank injection liner within normal temperature reservoir

Five month project delay. Stimulation phase of project will complete in October 2012.

Project Objectives are:

- To develop and demonstrate the concept of stimulating permeability by processes such as shear reactivation and thermal contraction to create a deep EGS reservoir in hot rocks by injecting water at low pressures.
- To investigate how such cold-water injection affects the hot dry rock system, both mechanically and chemically (e.g. dissolution) and how such processes contribute to the EGS.
- To demonstrate the technology used to monitor and validate the stimulation and sustainability of such an EGS.
- To develop an EGS research field laboratory that can be used for testing EGS stimulation and monitoring technologies including new high temperature logging tools that may be developed by others.

Relevance to the DOE Geothermal Technology Program

- Thermal mechanisms including shear reactivation and thermal contraction in tight rocks near hydrothermal reservoirs may be low hanging fruit in respect to creating future EGS systems.
- Shear reactivation and other thermal mechanisms of fracturing rocks with self-propping along asperities may be an alternative to hydraulic fracturing and the use of proppants.
- This project may generate about 5 megawatts of EGS-derived steam if a Power Purchase Agreement necessary to justify the construction of a new power plant is obtained.

Challenges

The primary challenge to the EGS project is the very high cost of drilling deep (3-4 km) wells in metamorphic and granitic rock and constructing relatively small (<50 MW) power plants at prices which are competitive with conventional power plants.

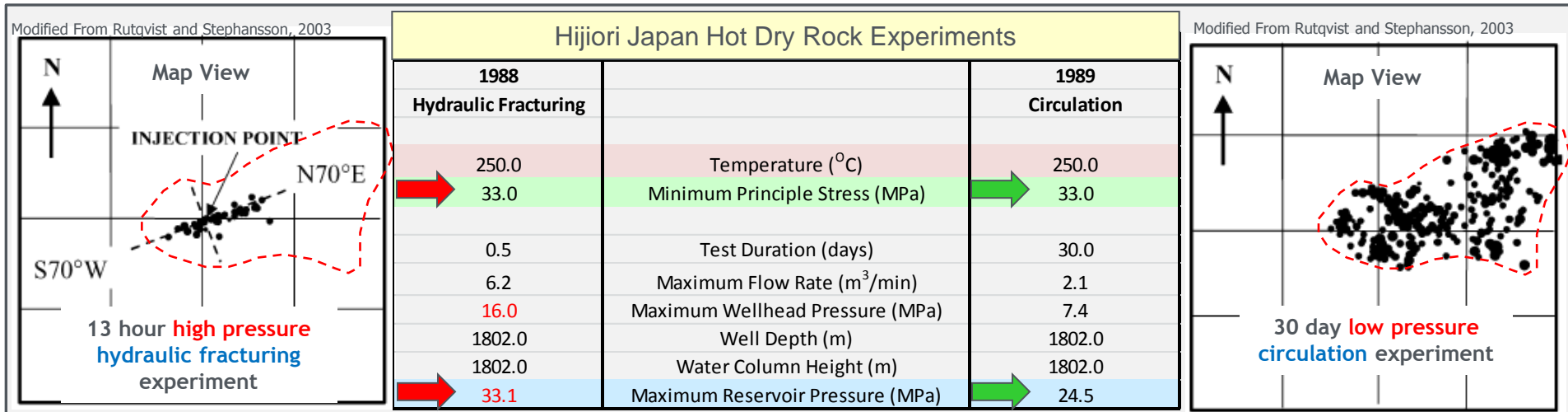
Our approach to stimulate an EGS

The EGS project is different than any previous injection project at The Geysers. The similarity to other injection projects is only that water is injected under a vacuum (about -13 psig) and falls to the bottom of the well by gravity. It is not pumped into the formation.

Key Issues and motivations

- **Increase steam production.**
Develop under-produced NW Geysers steam production
- **Mitigate NCG concentrations in steam from high temperature reservoir**
- **Stimulate wells to enhance permeability**
- **Achieve 100% mass replacement**
Support sustained electrical production for future development
- **Address public concerns on injection-induced seismicity.**

Calpine has successfully demonstrated the creation of an EGS at The Geysers

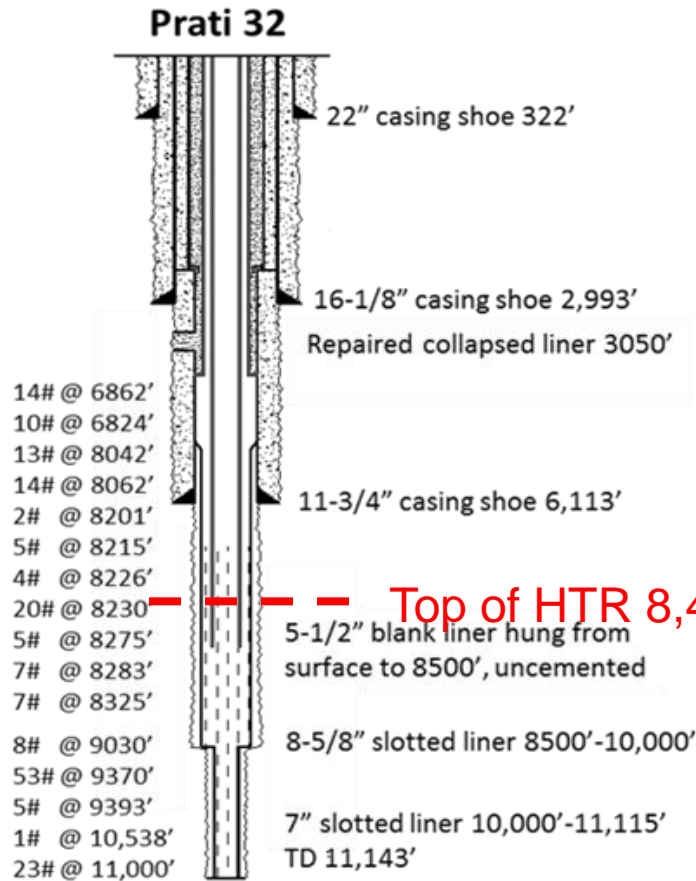


High Pressure Hydraulic Fracturing

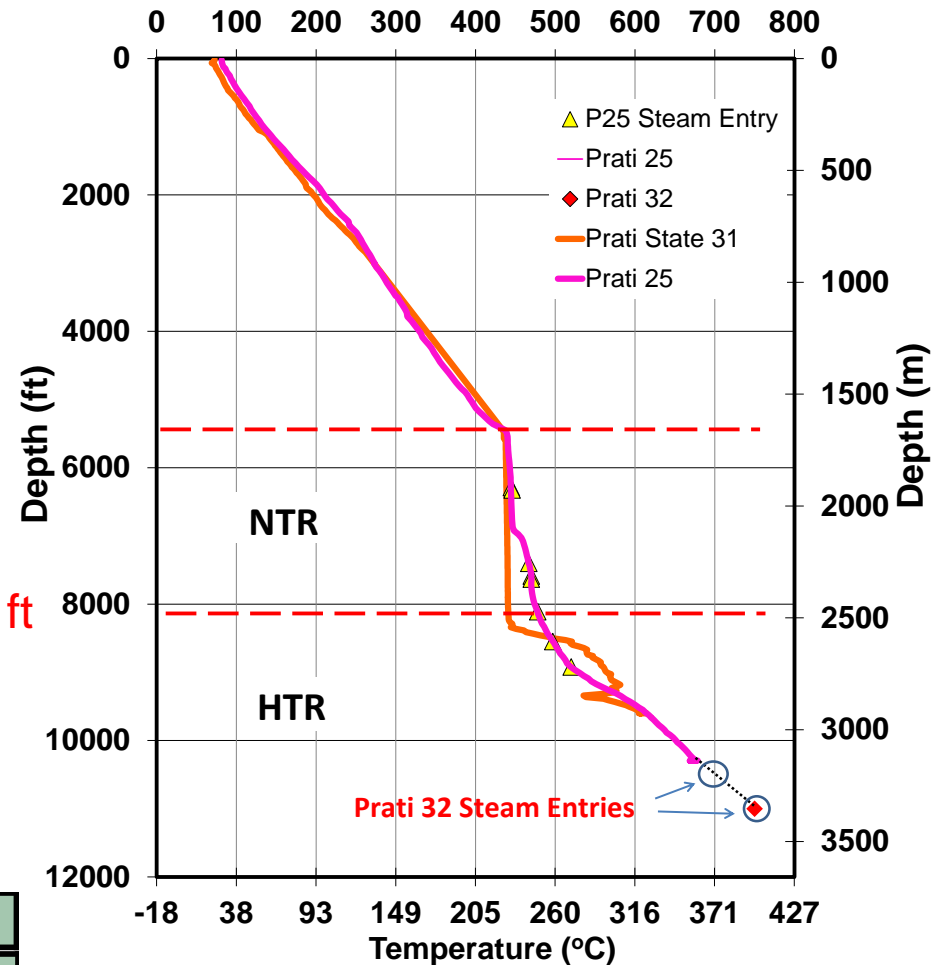
Low Pressure Thermal Fracturing

Avoids potentially damaging hydraulic fracturing and promotes gradual shear reactivation of existing fractures and thermal contraction

The NW Geysers EGS project is to demonstrate that a cloud of fractures can be created by thermal forces such as shear reactivation and thermal contraction rather than hydraulic, high pressure fracturing in which a single fracture set may result.

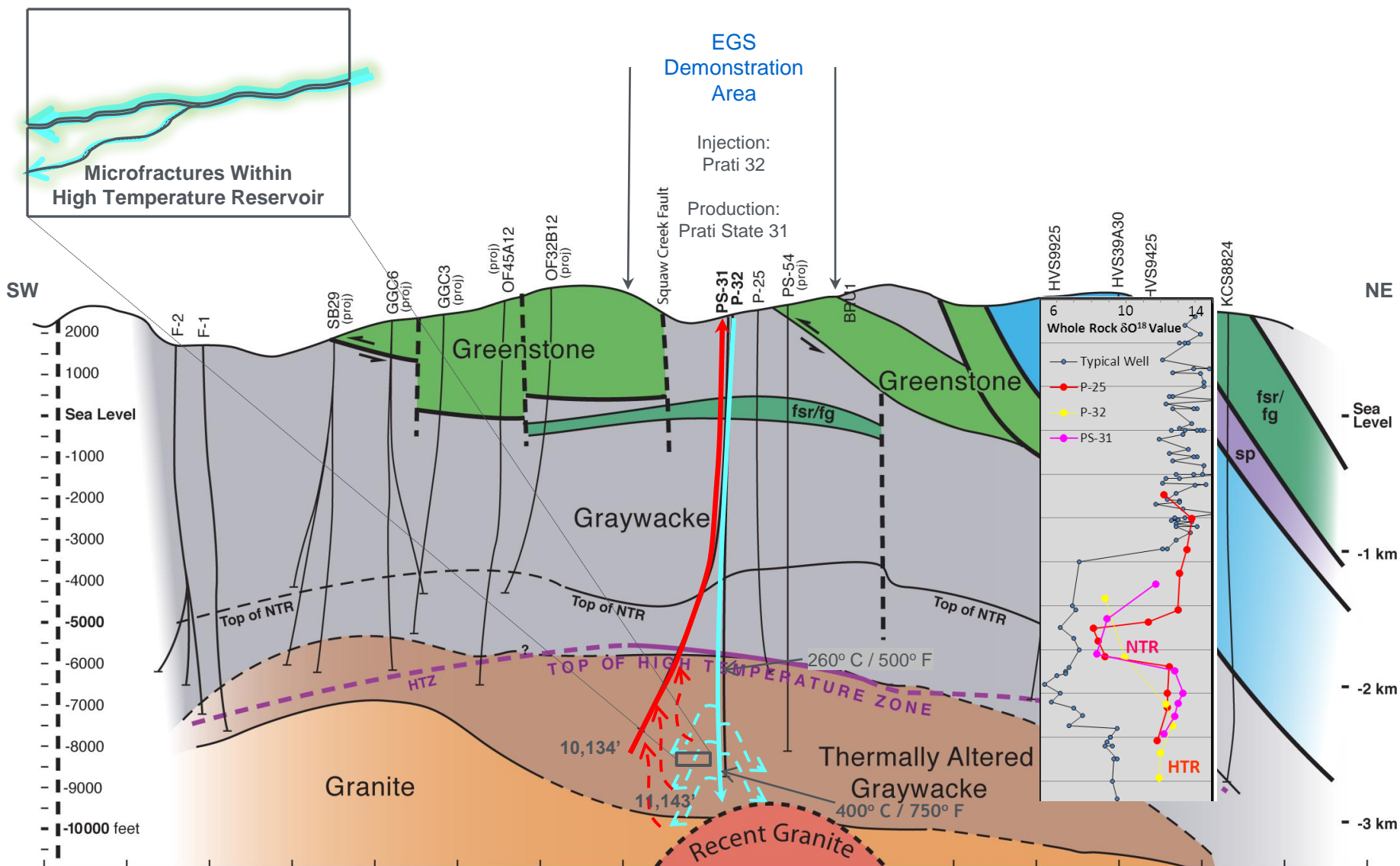


Top of HTR 8,400 ft



Maximum temperature recorded with a Kuster mechanical tool 750°F (400°C)

Flow Testing			Geochemistry			
KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H ₂ S (ppmw)	Cl (ppmw)	
84	100	340	5.9	1380	72	



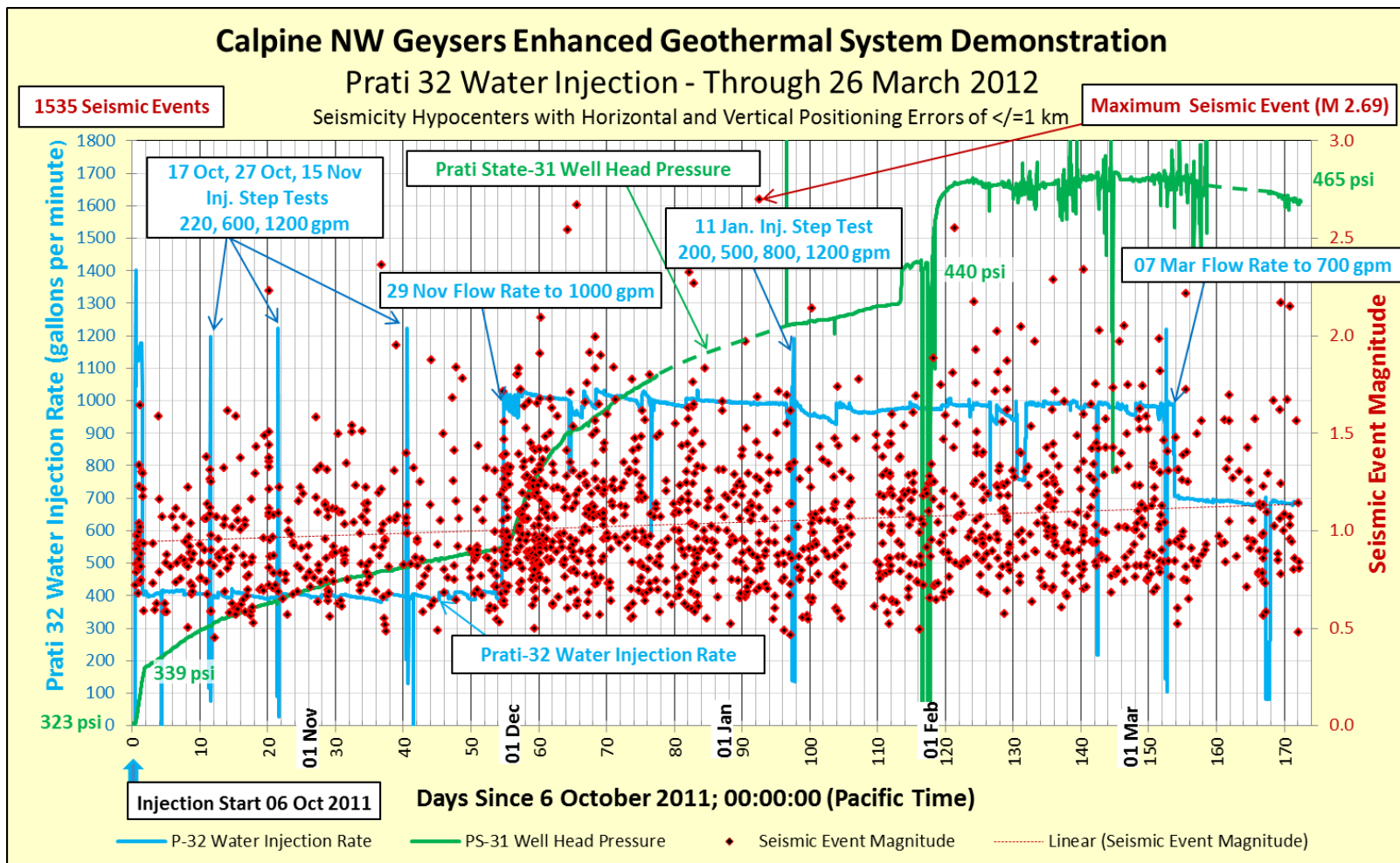
- **Prati State 31 (PS-31) and Prati -32 (P32) recompleted as a production-injection well pair (respectively) in September 2011**
- **Injection to P-32 began on October 6, 2011; monitored continuously.**
- **A cloud of microseismicity began to form almost immediately when injection in Prati 32 started.**
- **Stimulation has included the continuous injection of water at 400 gpm, 1000 gpm and 700 gpm.**
- **Prati 32 injection into 750 °F rock at 11,000 ft depth has created an EGS in hot dry rock (HDR) as evidenced by MEQ's, isotopic data, temperature and pressure data, and flow rate responses by PS-31.**
- **Established a connection between the HDR reservoir and the overlying normal temperature reservoir**

Accomplishments, Results and Progress

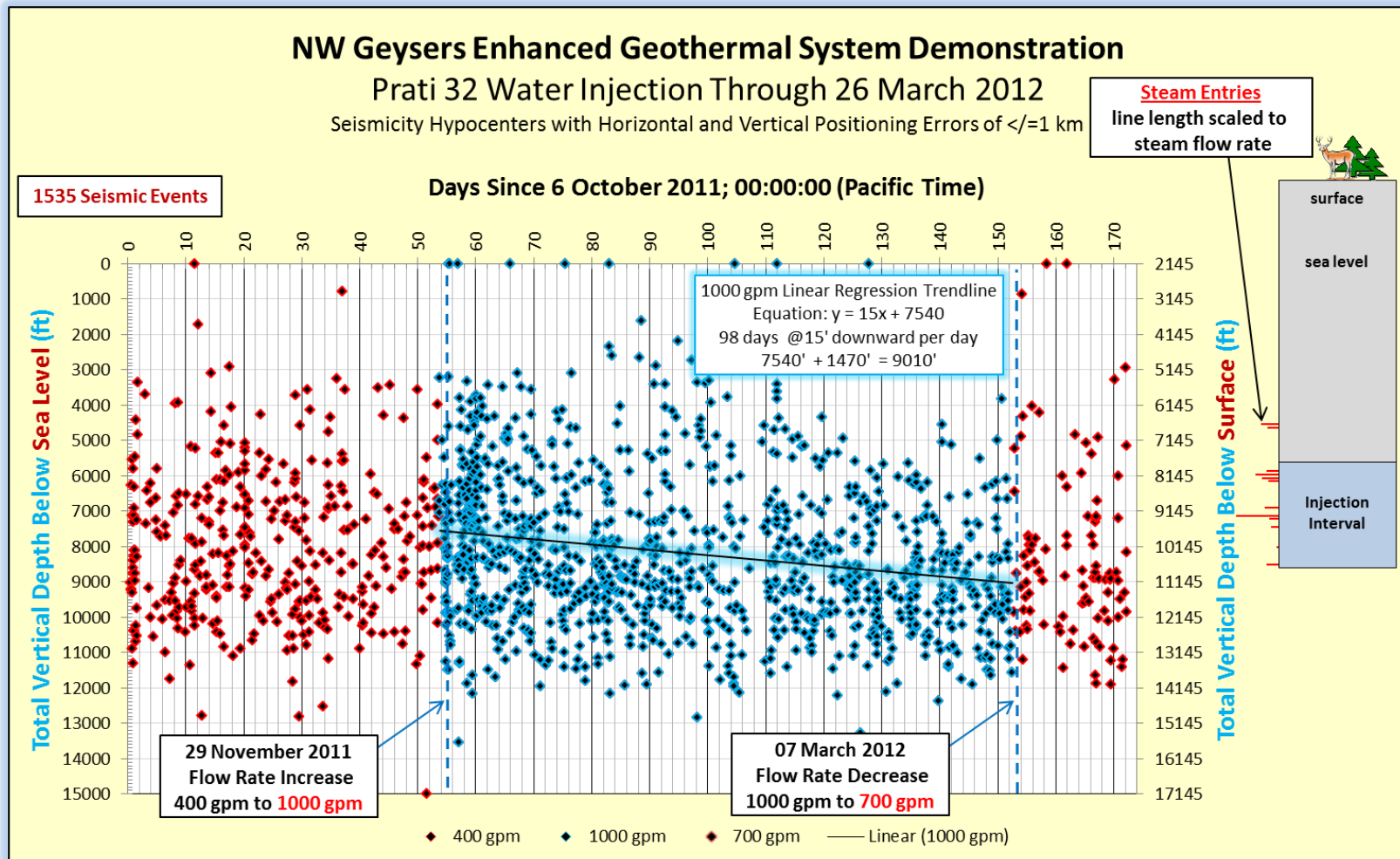
P-32 injection resulted in a PS-31 wellhead pressure increase from 323 to 465 psig.

The frequency of microearthquakes is directly related to injection rates.

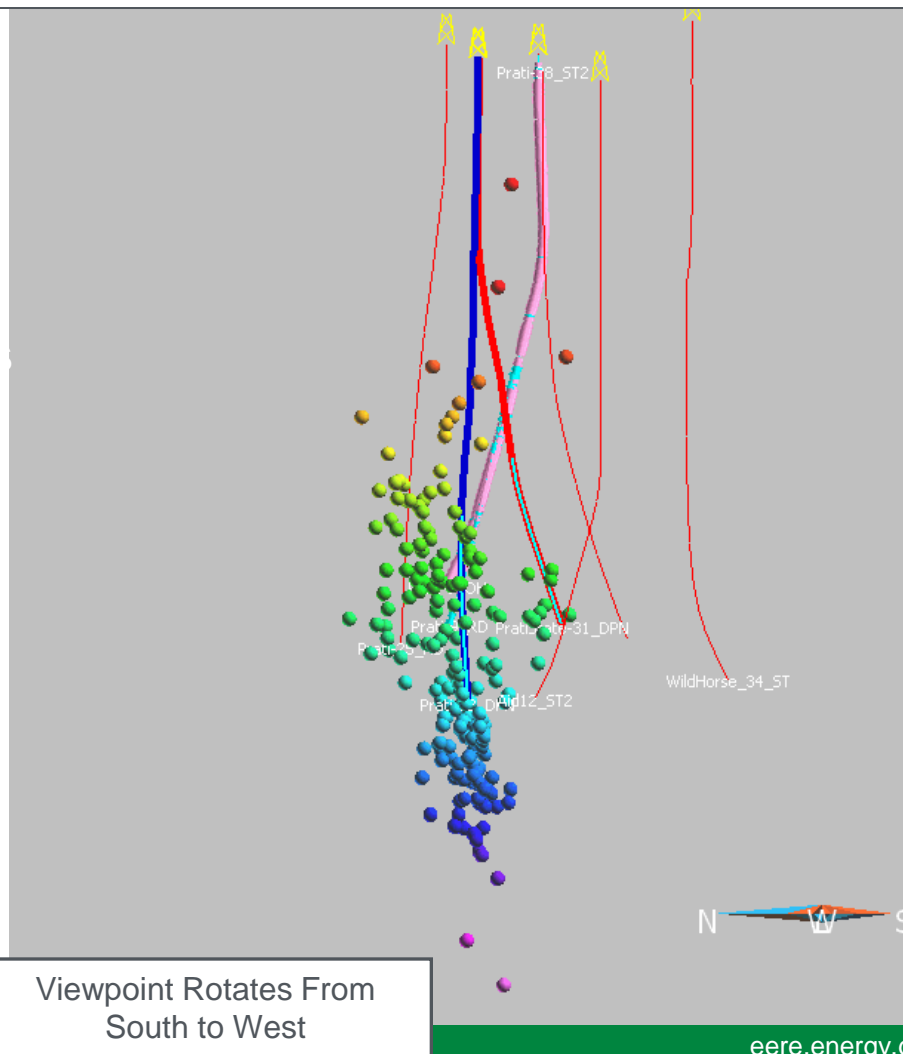
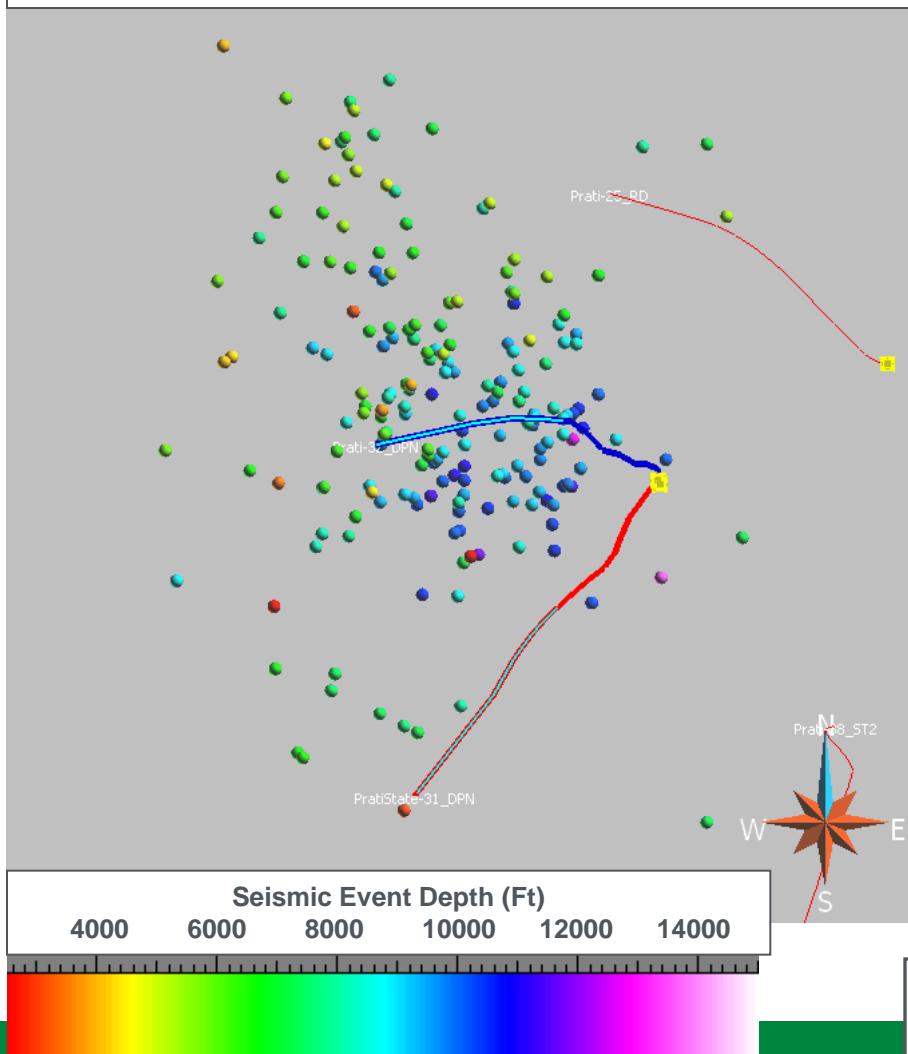
The maximum microearthquake is M_w 2.69. This event was not felt in nearby communities.



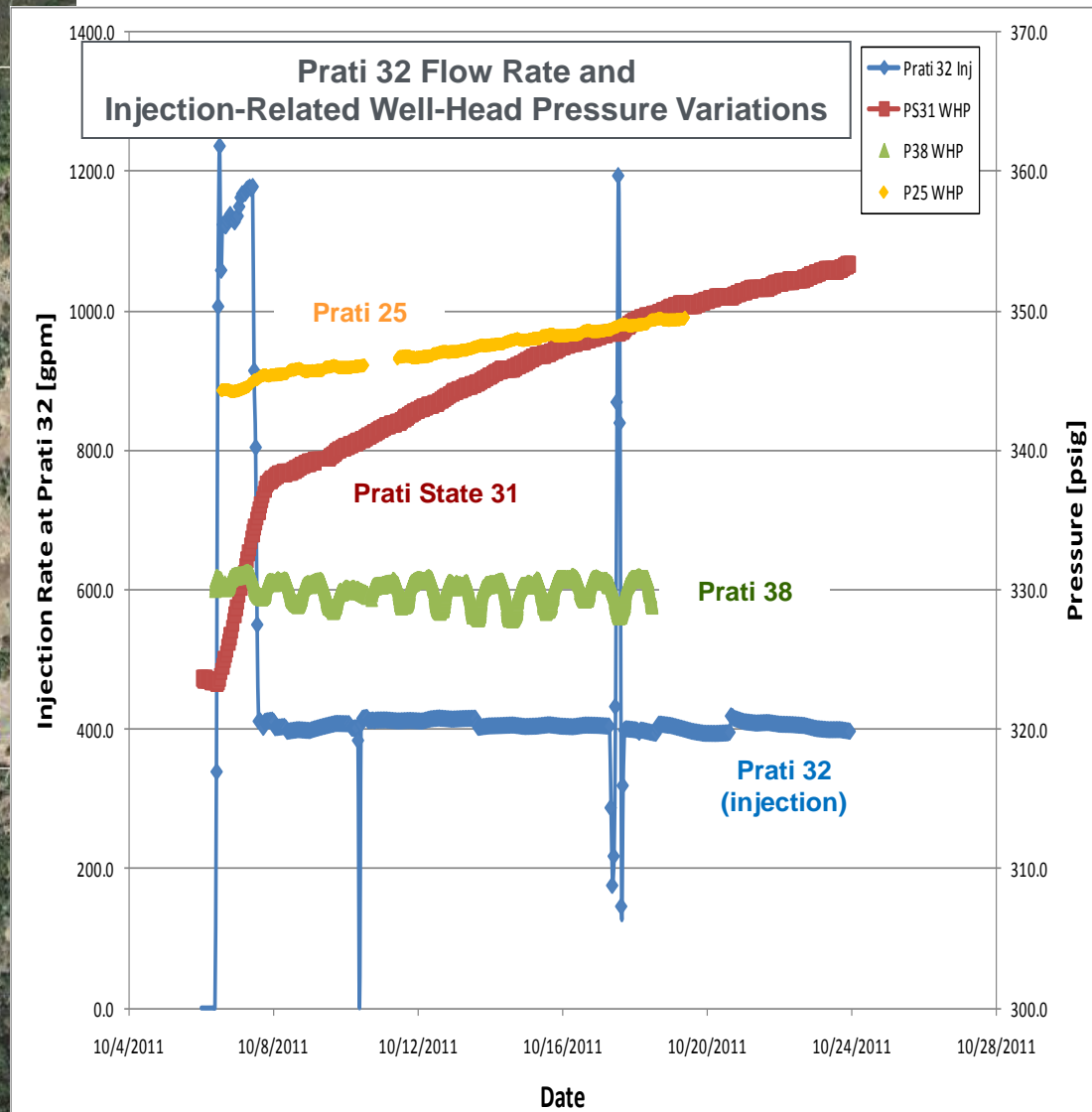
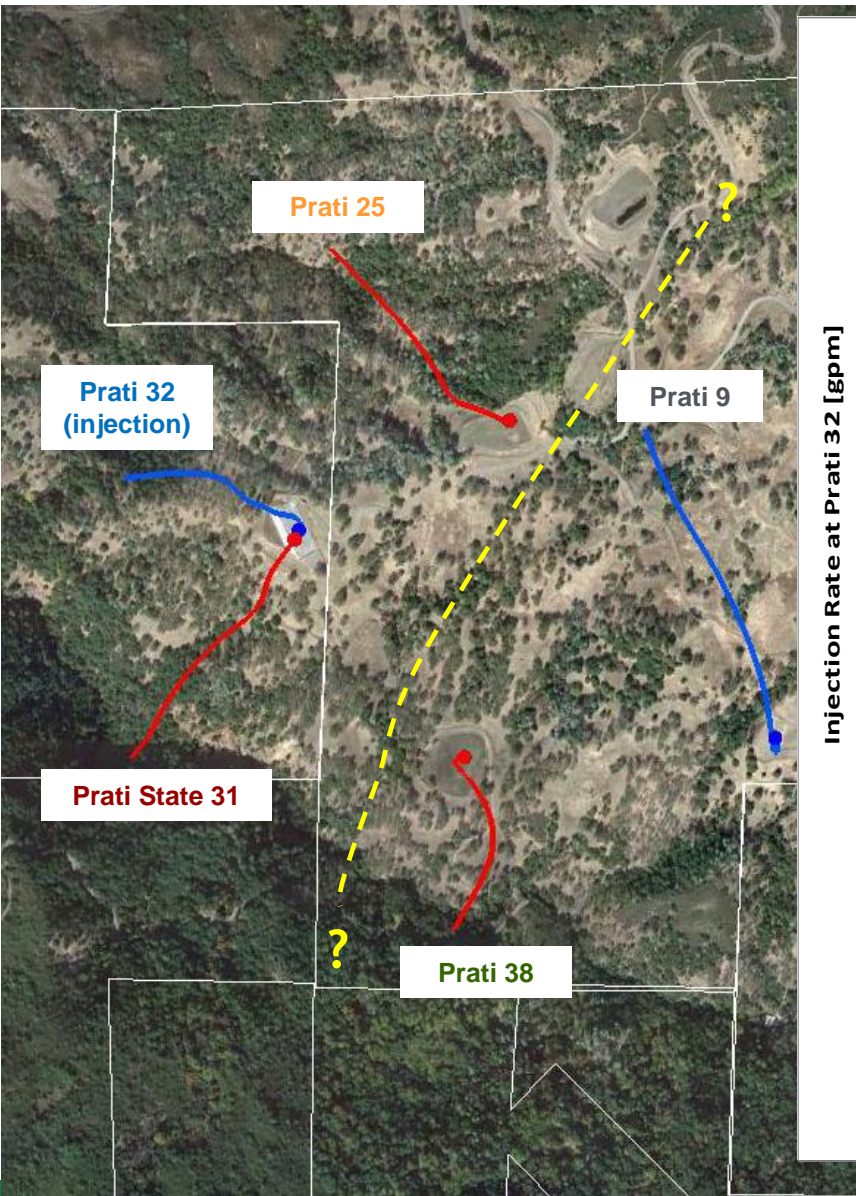
For the 1000 gpm injection period:
A linear regression trendline indicates that seismicity is trending downward at ~ 15 feet /day



Seismic Event Hypocenters Suggest Preferential Water Movement NNW / SSE Along a Tilted Zone of Higher Permeability



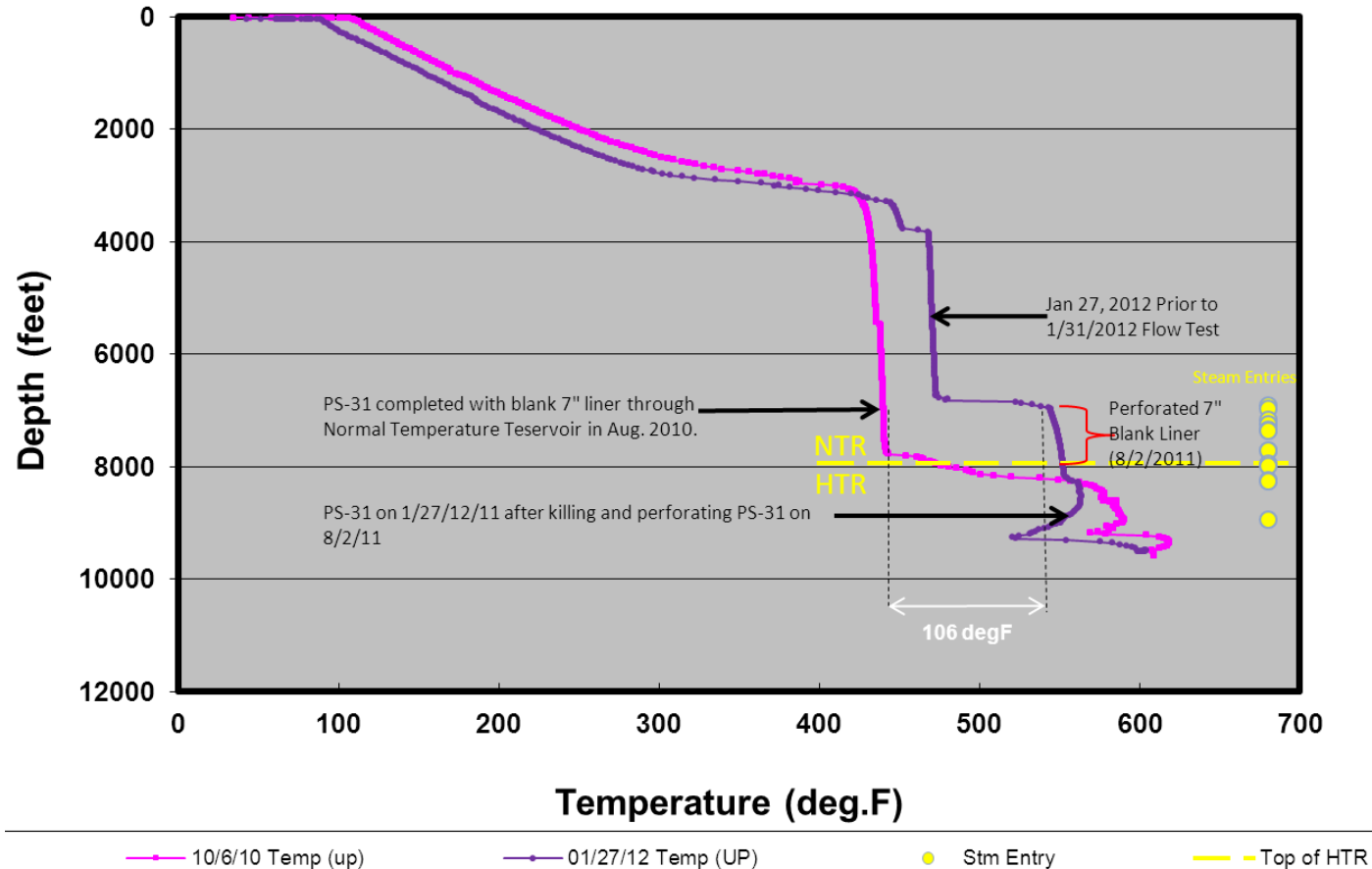
Accomplishments, Results and Progress



Following the injection in Prati 32, the static temperature in PS-31:

- Increased from about 450 degF to about 550 degF in the NTR and became superheated.
- Decreased in the HTR probably due to “killing” the well prior to perforating the liner through the NTR.
- Remained near a maximum of 610 degF at the bottom of the well.

Prati State 31 Static Temperature Traverses 2010 and 2012



A connection between the HTR and NTR is established.

PS-31 Flow Test Results January 31, 2012

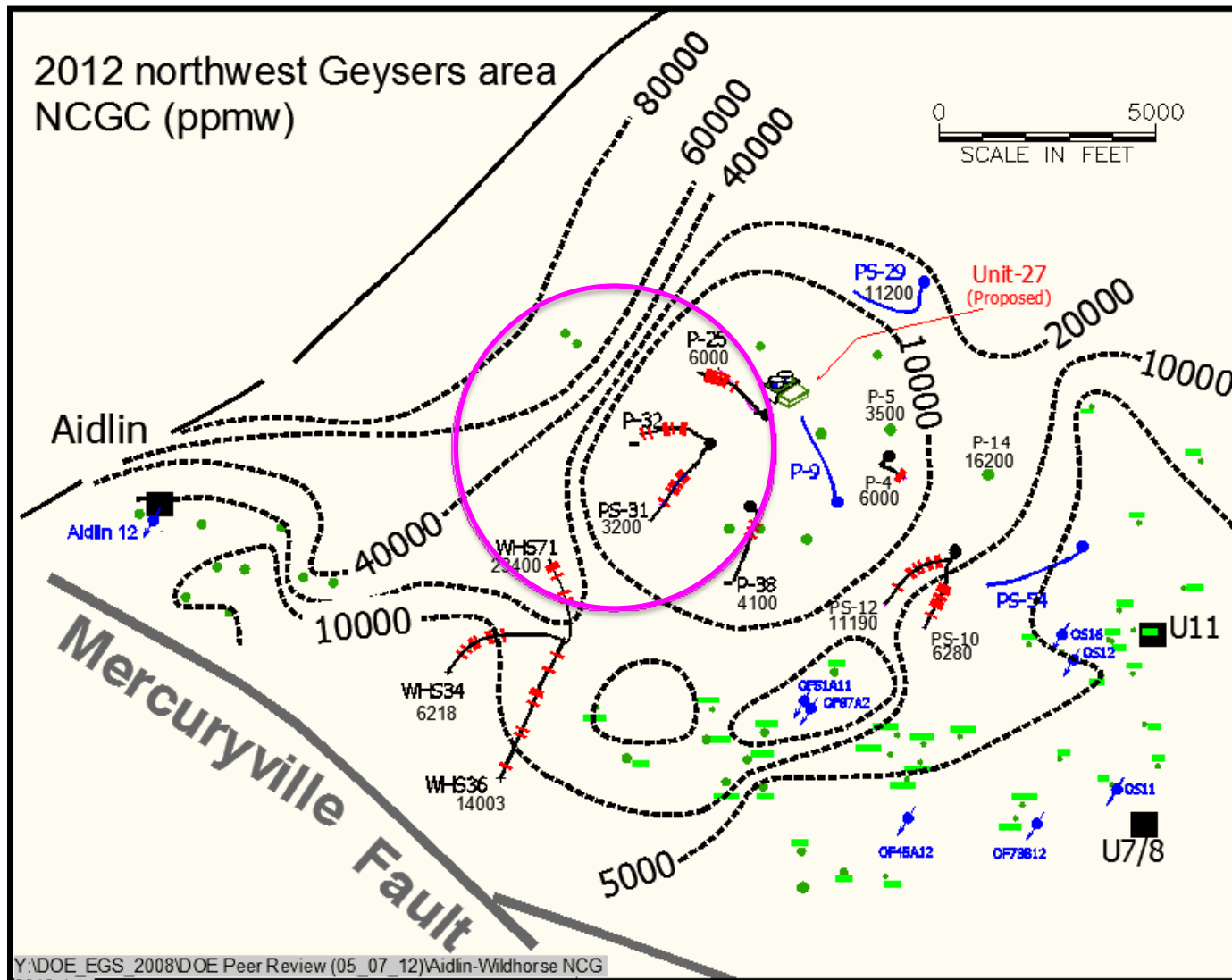
- Flow rate of PS-31 increased from 55 KPH prior to the October 2011 stimulation, to 72 KPH when tested in January 2012. The flow rate is anticipated to increase to about 94 KPH now that the un-needed 7" blank liner is pulled from well.
- Total NCG decreased more than 90% following the injection of water at P-32.
- Note Cl concentration is only marginally changed by injection of meteoric water as elsewhere at The Geysers.



WELL	Flow Testing			Geochemistry		
	KPH (klbs/hr)	WHP (psig)	SIWHP (psig)	NCG (wt.%)	H ₂ S (ppmw)	Cl (ppmw)
PS-31	55	100	320	3.9	1280	135
PS-31	72	100	465	0.3	550	125

Test prior to October 2011 stimulation →

January 31, 2012 test results →

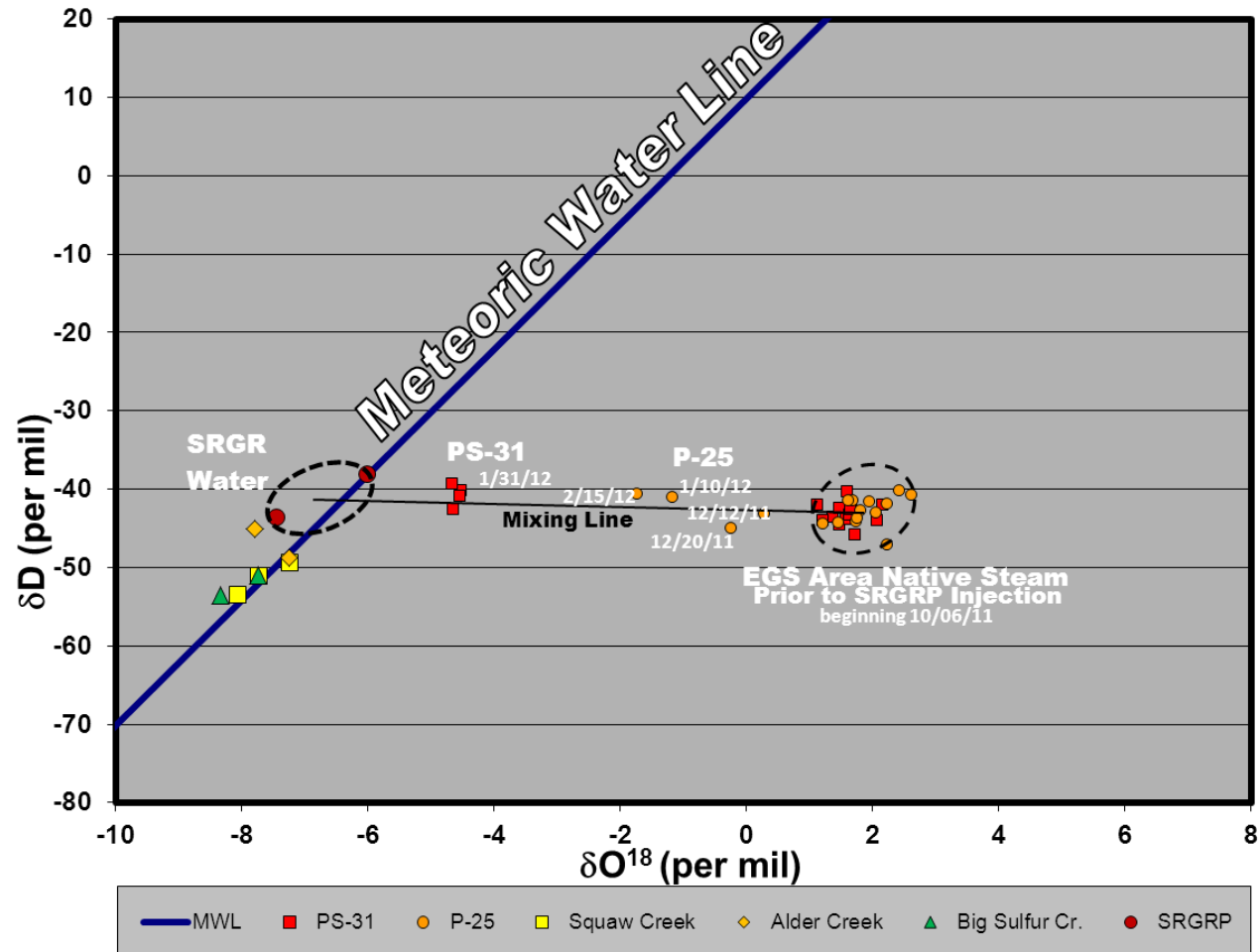


Isotopic Mixing of SRGRP Water and Native Steam in PS-31

75% of the steam produced by PS-31 is derived from SRGRP injected into the Prati 32 injector.

45% of the steam produced by P-25 is SRGRP water.

PS-31 is capable of producing 94 KPH of native and IDS steam with about 71 KPH being derived from SRGRP water injected into Prati 32.



At Prati State 31:

- Pulled upper 7" liner to increase deliverable steam (April 2012)
- Construct pipeline to existing production (Summer 2012)
- Deliver steam to existing Geysers power plants (Fall 2012)
- Monitor, sample and log PS-31 through FY2013



At Prati 32:

Injection Steps for the Stimulation:

- 700 gpm: until May 15, 2012
- 400 gpm: May 15, 2012 – July 15, 2012
- 0 gpm: July 15, 2012 – September 15, 2012
(or when PS-31 is on production)



At Calpine Visitor Center:

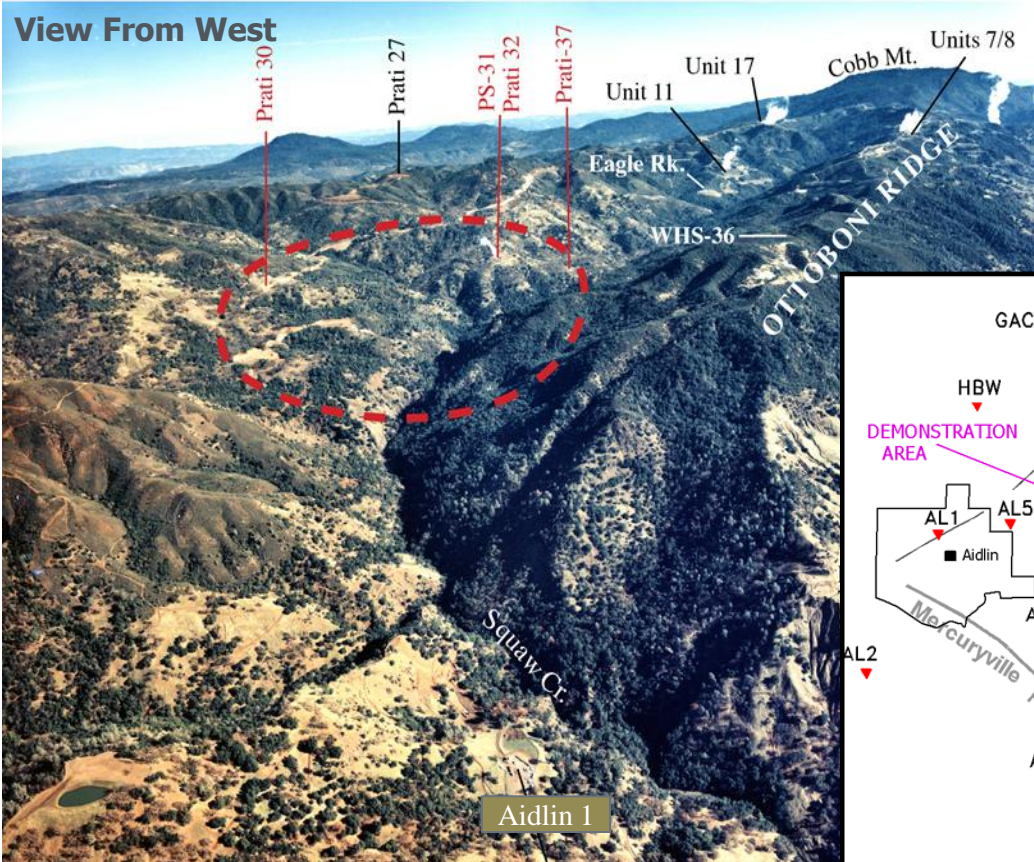
Complete the construction of new exhibits in July 2012.



Calpine is seeking a Power Purchase Agreement (PPA) to sell electricity from the proposed Wild Horse power plant sited less than 2500 feet from PS-31. If a PPA is obtained, existing production will be connected and the acreage adjacent to the EGS Demonstration Site may be developed.

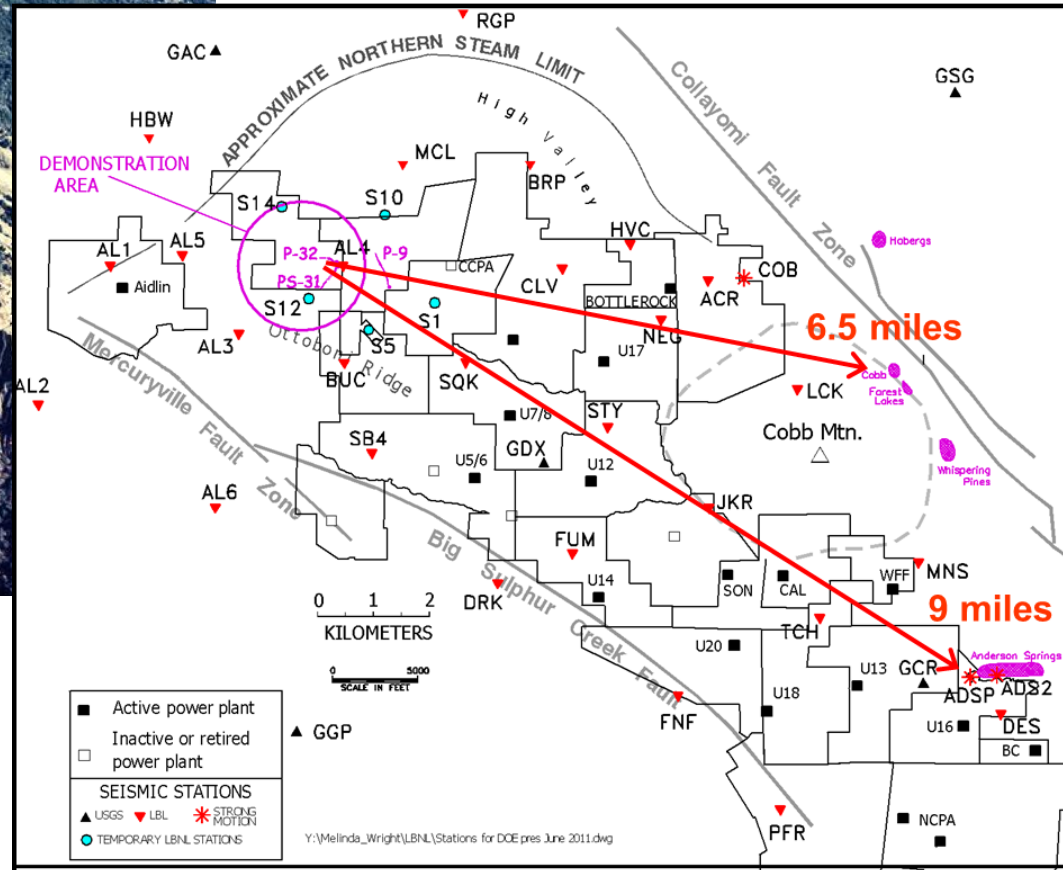


Future Directions – Additional EGS Development Area



The undeveloped EGS Demonstration Area is 7 to 9 miles from the nearest sensitive communities.

There are approximately 1100 undeveloped acres in the vicinity of the EGS Demonstration Area which are underlain by a high-temperature, hot dry rock reservoir.



Cold water injected under vacuum into P-32 has created a cloud of fractures in hot dry rock where temperatures reach 750°F. The temperature in the overlying NTR reservoir of PS-31 has increased by more than 100°F. About 90 kph of injection-derived steam with dramatically lower NCG concentrations than native steam can be produced from PS-31 and P-25. About 5 MW equivalent of new steam may result if the proposed Wild Horse Power Plant is constructed near the EGS demonstration.

	FY2011	FY2012
Milestones	<p>Recompleted PS-31 and P-32 for production and injection, respectively.</p> <p>Tested PS-31 after perforating, and before stimulation began, with temperature & pressure logging and geochemical sampling.</p> <p>Began stimulation experiment October 6, 2011.</p> <p>Monitoring and logging of EGS wells initiated.</p>	<p>Completed temperature & pressure logs prior to flow test.</p> <p>Flow test indicated a deliverability of 94 kph at 100 psi assuming 7" liner was removed. NCG concentrations in steam lowered by >90%.</p> <p>Pulled liner from PS-31 on April 3, 2012.</p> <p>Continued MEQ monitoring</p>
Results	Completed 10/6/2011	Completed as of April 4, 2012